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Simulation of the Emission and Dispersion of Gaseous Pollutants Emitted from Power Plant and the Potential Environmental Impacts: A Case Study

Fatma A. Slama[1], Mohamed M. Aboabboud[2], and Hesham G. Ibrahim[3, *]

1) Higher Institute of Science and Technology, Gharaboulli, Libya.
2) Chemical Engineering Department, Faculty of Engineering, Elmergib University, Gharaboulli, Libya.
3) Marine Mechanical Engineering, Faculty of Marine Resources, Alasmarya Islamic University, Zliten, Libya.

***Corresponding author:** h.ibrahim@asmarya.edu.ly

محاكاة انبعاث وتشتت الملوثات الغازية المنبعثة من محطة توليد الطاقة والتأثيرات البيئية المحتملة: دراسة حالة

فاطمة علي سلامة[1]، محمد محمد أبوعبود[2]، وهشام جهاد إبراهيم[3، *]

1) المعهد العالي للعلوم والتقنية، القره بوللي، ليبيا.
2) قسم الهندسة الكيميائية، كلية الهندسة، جامعة المرقب، القره بوللي، ليبيا.
3) قسم الميكانيكا البحرية، كلية الموارد البحرية، الجامعة الأسمرية الإسلامية، زليتن، ليبيا.

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Abstract

The polluting gas flow and emission levels emitted from the Zawia combined Power Plant (ZCPP) in-northwestern Libya were estimated using an Aspen-Hysys v.8.0 simulator which was performed for the plant based on the actual operating conditions of the power plant in steady state operation. Then, the air dispersion modeling tool (Disper V4.0 software) was used to estimate the concentration of these pollutants emitted throughout the surrounding areas, and the WAR algorithm v.1.0.17 was used to check the potential environmental impacts of the gas emissions from ZCPP. Simulation results for the studied power unit showed that the thermal efficiency and net energy output are equivalent to the realistic values of the unit, which indicates that the estimated emission concentration is identical to the real emissions from this unit and that the primary emitted pollutant is nitrogen oxides, whose values exceeded the selected international standard limits. Based on the seasonal climatic conditions of the region, the results of simulating the dispersion of nitrogen oxides showed that the emissions reach areas far from the emission source with high-level concentrations, which may have negative effects on the environment and public health according to WHO standards and previous studies related to air quality. According to the current scientific literature, the results of the eight indicator values derived from the WAR algorithm of the total production rate confirm the potential environmental impacts of the power plant per hour as environmentally harmful. Moreover, the amount of carbon dioxide emitted from the combustion process increases the greenhouse effect. The main conclusion reveals that the atmospheric air of the surrounding regions of Zawia city is polluted with nitrogen oxides resulting from the studied power plant as one of the primary sources of nitrogen oxides in the study area, which may have a negative impact on the environment and the health of the inhabitants.

Keywords: *Aspen-Hysys; Disper; Dispersion; Emission; Power plant; WAR algorithm.*

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الملخص

تم تقدير مستويات التدفق والانبعاثات الغازية الملوثة المنبعثة من محطة توليد الزاوية المزدوجة (ZCPP) في شمال ليبيا باستخدام برنامج المحاكاة Aspen-Hysys v.8.0 والتي تم إجراؤها للمحطة بناءً على ظروف التشغيل الفعلية لمحطة توليد الطاقة في حالة تشغيل مستقرة. ثم تم استخدام برنامج نمذجة تشتت الهواء برنامج (Disper V4.0) لتقدير تركيز هذه الملوثات المنبعثة في جميع أنحاء المناطق المحيطة، كما تم استخدام خوارزمية WAR v.1.0.17 للتحقق من الآثار البيئية المحتملة لانبعاثات الغازات من المحطة. أظهرت نتائج المحاكاة لوحدة الطاقة المدروسة أن الكفاءة الحرارية وصافي الطاقة الخارجة متكافئتان مع القيم الواقعية للمحطة، مما يشير إلى أن تركيز الانبعاث المقدرة مطابقة للانبعاثات الحقيقية من هذه المحطة وأن الملوث الرئيسي المنبعث هو أكاسيد النيتروجين، والذي تجاوزت قيمه الحدود المعيارية الدولية المختارة. وبناءً على الظروف المناخية الموسمية للمنطقة، أظهرت نتائج محاكاة تشتت أكاسيد النيتروجين أن الانبعاثات تصل إلى مناطق بعيدة عن مصدر الانبعاث بتراكيز عالية المستوى والتي قد يكون لها آثار سلبية على البيئة والصحة العامة وفقًا لمعايير منظمة الصحة العالمية والدراسات السابقة المتعلقة بجودة الهواء. ووفقًا للأدبيات العلمية الحالية، تؤكد نتائج قيم المؤشرات الثمانية المستمدة من WAR لمعدل الإنتاج الإجمالي للتأثيرات البيئية المحتملة للعملية في الساعة على أنها ضارة بالبيئة. علاوة على ذلك، فإن كمية ثاني أكسيد الكربون المنبعثة من عملية الاحتراق تزيد من ظاهرة الاحتباس الحراري. تشير نتائج الدراسة أن الهواء الجوي للمنطقة المحيطة بمدينة الزاوية ملوث بأكاسيد النيتروجين الناتجة عن محطة توليد الكهرباء قيد الدراسة والتي تعتبر أحد المصادر الرئيسة لأكاسيد النيتروجين في منطقة الدراسة مما قد يكون له تأثير سلبي على البيئة وصحة السكان القاطنين بها.

الكلمات الدالة: أسبن هايسيس؛ ديسبر؛ الانتشار؛ الانبعاث؛ محطة الكهرباء؛ خوارزمية WAR.

1. Introduction

Air pollution is one of the most serious environmental problems in the world. Where Air pollution results in 7 million premature deaths across the world each year according to WHO. These concerns have led to the creation of certain organizations that regulate legislation and emissions regulations to address these problems due to, poor air quality in cities and have been associated with major health issues (Sahu *et al*., 2021; and Al-Azmi *et al*., 2008).

Gaseous pollutants emissions from natural gas and heavy fuel oil burning in power plants are regarded as a public health hazard and a source of environmental degradation. Pollutant gaseous pollutants generated by power plants, such as nitrogen oxides and sulfur dioxide gases, can have serious health repercussions if reach high concentrations in the environment. To understand the impact of the pollutants emitted, mathematical models are frequently employed to anticipate the time and spatial distribution of the emissions, particularly in metropolitan settings. In addition to academic applications, air quality models are used to conduct environmental evaluations and make decisions to limit air pollution in metropolitan areas (Al-Awadhi and Yassin, 2010).

The hazardous and particle pollutants generated by thermal power facilities are dispersed across broad areas (Kouprianov, 2002; and Hart *et al*., 1995). The severe health and environmental consequences of thermal power plant emissions are widely known (Dopatka *et al*., 2003; and Kouprianov *et al*., 2002). Many kinds of research on thermal power plant emissions have verified the seriousness of the implications of emitted air pollutants on global warming and health effects (Islas *et al*., 2002; Garg *et al*., 2001; Gillani *et al*., 1998; and Ryerson *et al*., 1998). In several regions of the world, air dispersion modeling has been

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combined with epidemiological evaluation to identify source-specific health consequences or environmental externalities (EC, 1995; Rowe *et al*., 1995; and ORNL, 1994). While some attempted to explain the disparities between these studies (Levy *et al*., 1999; and Krupnick & Burtraw, 1996), significant differences persisted, which were mostly ascribed to atmospheric modeling assumptions. Thus, computer techniques combined with both deterministic and statistical approaches give excellent instruments for studying the environmental effect of contaminants. Also allow for the prediction of likely outcomes and aid in the development of environmental protections. These verified designs based on real-world and laboratory data aid in confirming the validity and compliance of novel procedures with Environmental Protection Agency regulations (EPA). As a result, air quality models are critical tools for assessing the impact of air pollutants on urban environments and human health (Gokhale & Khare, 2004).

Libya has a total installed power generating capacity of 33,980 MW/hr in 2012, with thermal power being the primary source; just a minor part uses renewable energy (such as wind and solar power). The use of fossil fuels accounts for 91% of the country's total power-producing capacity (GECOL, 2014). Libya's environmental rules were established in 1998 when the General People's Committee authorized the Environment Public Authority, and National Environmental Quality Standards (NEQS) were adopted in 2008. Because of a lack of emission inventories and sufficient environmental impact assessment procedures for power plant installation, the consequences of thermal power plant pollution are not widely recognized in these domains. The majority of thermal power plants were built before 1998, and the other power plants were built after 2000 without dispersion modeling (LY, 2008). So, it is extremely difficult to estimate the pace of degradation of air quality in the absence of emission inventories and an air quality database.

So, the purpose of this research was to assess the potential environmental impact of the gaseous pollution emitted from power plants on the air quality of the neighborhood areas (Zawia combined power plant as a case study). The air dispersion modeling program (Disper V4.0) was used to anticipate the concentration of these pollutants in the surrounding zones, also the WAR algorithm was used to analyze the Potential Environmental Impacts (PEIs) of gas emissions from the studied power plant.

2. Materials and Methods

2.1. Study area

The Zawia combined power plant is one of Libya's major power plants, located near the city of Zawia, located on the Libyan Mediterranean Sea coast about 45 km west of Tripoli. Latitude: 32º78'83", Longitude: 12º67'35", and this area is characterized by a flat topographical landform. It is inhabited by over 300,000 residents.

2.2. Meteorological data

The meteorological parameters data used in this simulation were taken from the surface weather observatory station at Tripoli International Airport and were typical of the whole examined area. From 2007 to 2017, meteorological data such as wind speed, wind direction,

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air temperature, and humidity were thoroughly examined (WF, 2017). The direction and velocity of the wind are used to calculate pollution dispersion in the atmosphere. Figure (1) depicts the wind rose diagram from 2007 to 2017.

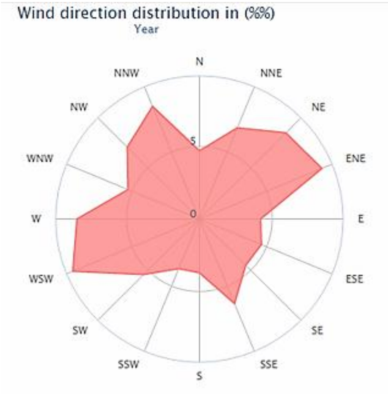

Figure 1. Wind rose directions for Zawia city (WF, 2017)

The prevalent winds in the Zawia region range from west-southwest to north-northwest, with a relatively high presence of wind blowing from the east-northeast. Zawia's climate is hot and semiarid. The average season data from the city's meteorological center on the wind was examined based on seasonal averages for each month's prevailing winds, as shown in Table (1) for a period of ten years (2007-2017), and the monthly regularity values were estimated individually.

Table 1. Average values of meteorological data (period 2007-17) of Zawia City (WF, 2017)

Months	Seasons	Wind directions & speed			Humidity	Ambient Temp.	Seasonal Data			
		Direction (degree)	kts	(m/sec)	(%)	(ºC)	Direction (degree)	(m/sec)	(ºC)	(%)
3	Spring	337	10	5.14	73	19	149.67	5.14	23.33	65.33
4		67	9	4.63	62	24				
5		45	10	5.14	62	27				
6	Summer	45	9	4.63	70	30	52.33	4.29	32.00	63.33
7		45	8	4.12	64	33				
8		67	8	4.12	62	33				
9	Autumn	45	8	4.12	64	30	149.67	4.12	25.67	68
10		157	8	4.12	64	26				
11		247	8	4.12	68	21				
12	Winter	247	9	4.63	69	16	254.67	4.80	15.00	64.67
1		247	9	4.63	67	13				
2		270	10	5.14	59	16				

2.3. Simulation processing of Zawia combined power plant

The Zawia combined power plant was simulated using real-world operational circumstances (By using Aspen-Hysys v 8.0) to predict the volume and concentration of gas released. Building a simulation model requires knowledge of process specifics as well as appropriate

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design and operating information. Table (2) displays the steady-state operational data used in power plant simulation.

Table 2. Operating data of Zawia combined power plant (ZCPP, 2016; and Fellah & Noba, 2016)

Data	Combined Power Plant
Operating efficiency	157.4 MW*2=314.8 MW GT 140.4 MW*1= 140.4 MW ST Total=455*3 units= 1,365 MW
Type of fuel	Natural gas
Capacity of Air compressor	427 m^3/sec
Operating temperature	1,517 ºC
Unit Thermal efficiency	43.75%
Actual excess air	88.6%
Relative Humidity	65%

2.3.1. Compositions of used fuel:

Table (3) present the composition and operating conditions of natural gas that used as fuel in Zawia combined plant.

Table 3. Natural gas composition supplied to Khoms Gas plant and Zawia combined plant (MCOG, 2016)

Comp.	*Unit*	*Value*
N_2	*mol.%*	0.71
CO_2	*mol.%*	2.023
CH_4	*mol.%*	86.98
C_2H_6	*mol.%*	9.35
C_3H_8	*mol.%*	2.33
$n\text{-}C_4H_{10}$	*mol.%*	0.63
Total	*mol.%*	**100**
M.Wt.	--	18.36
Density	*kg/Nm³*	15.69
T.S.	*g/Nm³*	0.0009
Feed Pressure	*bars*	21
Feed Volumetric Flow rate	*m³/hr*	175.1

2.3.2. Chemical reactions and pollutants formation:

The primary processes involved in natural gas combustion presented in Table (3) are as follows (Ibrahim *et al.*, 2012a);

$$CH_4+2O_2 \rightarrow CO_2 + 2H_2O \quad \text{..... (1)}$$

$$2C_2H_6 + 7O_2 \rightarrow 4CO_2 + 6H_2O \quad \text{..... (2)}$$

$$2C_3H_8 + 10O_2 \rightarrow 6CO_2 + 8H_2O \quad \text{..... (3)}$$

$$C_4H_{10} + 6.5O_2 \rightarrow 4CO_2 + 5H_2O \quad \text{..... (4)}$$

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With a conversion rate of 100% at operating conditions (Ibrahim *et al.*, 2012a); and side-reactions are;

$$2H_2S + 3O_2 \rightarrow 2SO_2 + 2H_2O \quad \text{..... (5)}$$

Sulfur compounds such that H_2S is fully converted at given operating conditions (Ibrahim *et al.*, 2012a), and;

$$N_2 + O_2 \rightarrow 2NO \quad \text{...... (6)}$$

where only 0.15% of the nitrogen contained in injected air is converted to NO (Ibrahim *et al.*, 2012a).

2.3.3. Assumptions:

To carry out thermal analysis of Zawia combined power plant by Aspen-Hysys V8.0, the following assumptions are adopted to doing the simulation;

- The conversion is 100 % in the combustion chamber (Full combustion).
- There are no particulates emitted.
- The station operates at a steady-state, neglecting the effect of the kinetic and potential energies.
- Heat loss from the system components is neglected (adiabatic). In the compressor and turbines are adiabatic.
- It's supposed worthless the mechanical losses.
- There aren't losses on the conversion energy.
- Concentration of S in feed is very small so neglected.

The fluid package used here is Peng-Robinson (PR) since it is the one that more it resembles with real data for power plants (AHGU, 2016).

2.4. Air pollutants dispersion processing

The estimated NOx released from the Zawia combined Power Plant stacks in the local environment was achieved by utilizing DISPER V4.0, an air pollution dispersion modeling program created by Canarina Environmental Software in 2007, and authorized by the US EPA (DUG, 2007). To evaluate the impact of the source on the environment. The average seasonal wind speeds and directions, together with emission rates, were used to compute the concentration distribution of NOx pollutants and depict the findings on a grid map.

2.5. Potential Environmental Impact (PEI) Processing

The WAste Reduction (WAR) algorithm assesses processes based on their possible environmental impact (PEI). The anticipated environmental impact of a chemical is defined as the effect a chemical would have on the environment if it were simply released into the ecosystem. The purpose of this technique is to reduce the PEI for a process rather than the quantity of waste (pollutants) produced by a process. The impact assessment technique is complex while being flexible enough to allow customers to focus on or deemphasize certain threats as needed for specific applications. The EPA authorized this software (Cabezas *et al.*, 1997, 1999; and Mallick *et al.*, 1996). Potential environmental impacts from eight categories

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are included in the WAR algorithm indices (Human Toxicity Potential by Ingestion, Human Toxicity Potential by Exposure, Terrestrial Toxicity Potential, Aquatic Toxicity Potential, Global Warming Potential, Ozone Depletion Potential, Smog Formation Potential, and Acidification Potential) (Cabezas *et al*., 1997, 1999; and Mallick *et al.*, 1996).

3. Results and Discussion

3.1. Simulation of Zawia combined power plant

A unit of the combined power plant of Zawia was simulated according to the data presented in Table (2) by using Aspen-Hysys (Fig. 2), the obtained results show that thermal efficiency and net-output power are equivalent in the calculated and real situations (Table 4), indicating that the estimated NOx and other emission concentrations are identical to the true emissions from this chimney.

Table 4. Comparison of a simulated and real Zawia combined power plant unit data

Data	***Units***	***Processes value***		***Deviation***
		Simulated	***Real***	
Output power per GT 1 (Gas Turbine No.1)	MW	157.33	157.35	-0.02
Output power per GT 2 (Gas Turbine No.2)	MW	157.33	157.35	-0.02
Output power per ST (Steam Turbine)	MW	140.42	140.4	+0.02
Output power per unit	MW	455.09	455.1	-0.01
Thermal efficiency per unit	%	43.50	43.75	-0.25
Operating temperature	K	1790	1790	0
Exit gas temperature from chimney	K	878	833	+45

The obtained results by Aspen-Hysys simulation of each unit of the power plant reveal that the simulated process for each one is identical to the present real case. The simulation of the power plant provides estimates of emission concentrations of NOx and other products Table (5) contains the flow rate and concentration results of gas emissions from the stacks of the simulated case.

Table 5. Gas emissions from Zawia combined power plant

Unit / Comp.	***Flow rate per unit***		***Flow rate per plant***		
	(kg/hr)	***(m^3/hr)***	***No. of units***	***(kg/hr)***	***(m^3/hr)***
O_2	7.59E+05	5.31E+05	The plant consists of three units each one containing of; - 2 gas turbines; - 2 HRSG; - 1 steam turbine; and - 1 stack (L=, ID=6.3 m) The plant containing 3 stacks.	2.28E+06	1.59E+06
N_2	2.82E+06	2.25E+06		8.46E+06	6.75E+06
NO	9.06E+03	6.77E+03		2.72E+04	2.03E+04
CO_2	6.68E+04	3.40E+04		2.00E+05	1.02E+05
H_2O	9.81E+04	1.22E+05		2.94E+05	3.66E+05
Total	**3.75E+06**	**2.95E+06**		**1.13E+07**	**8.85E+06**

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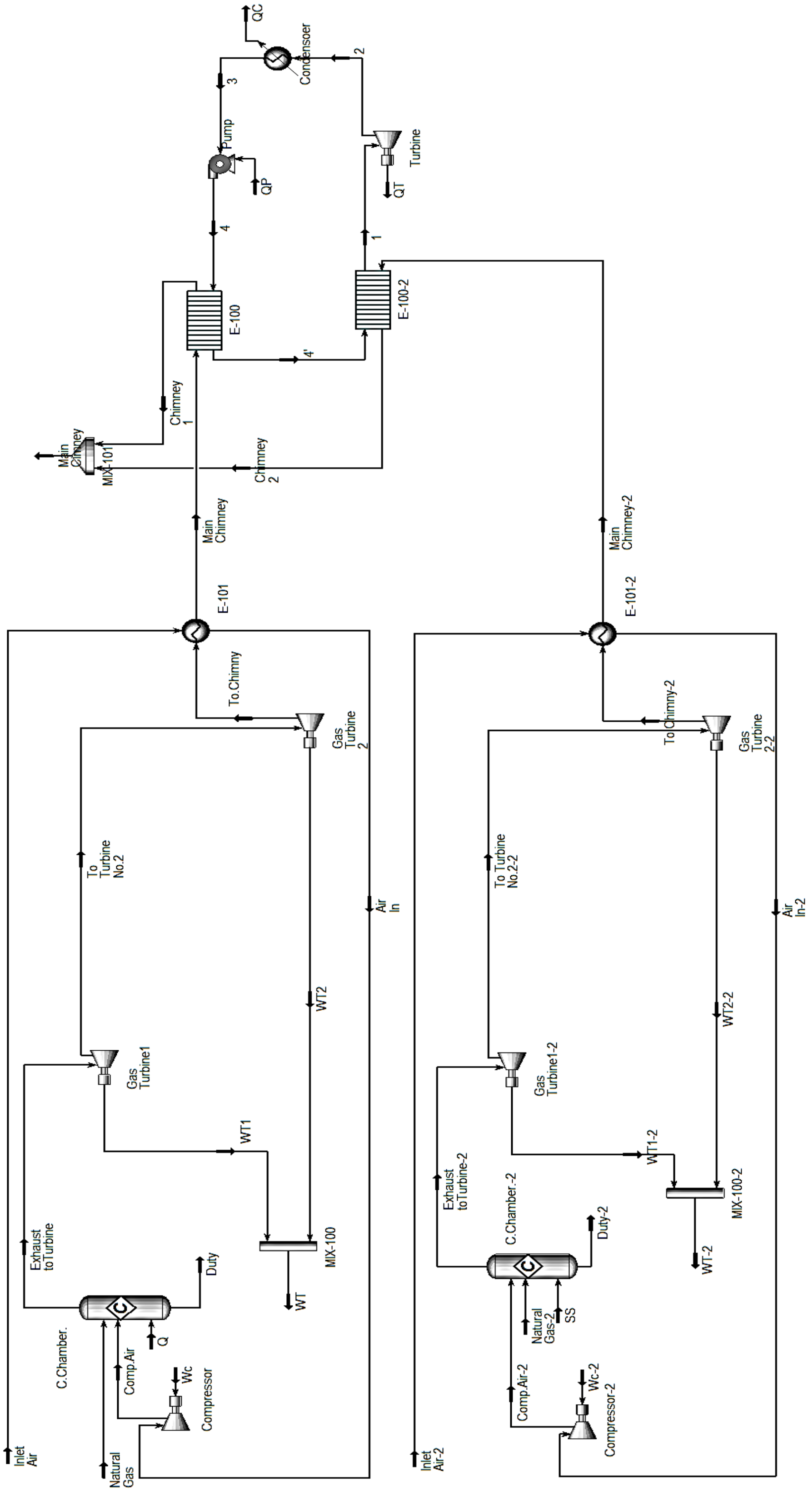

Figure 2. Simulated Scheme of Zawia combined power plant

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Table (6) compares the findings to five international codes: American (USEPA), Egyptian (EG), European (ECE), Saudi (KSA), and Libya (LY). The (+) symbol signifies the percentage of the gas's emission rate exceeding a particular standard limit, whereas the (-) sign shows the percentage of the gas's emission rate that falls below a specific standard limit. Nitrogen oxides released from the power plant surpass all standard limits established by the USEPA, ECE, KSA, and LY many times, amounting to percentage deviations ranging from 734.3% (LY) to 1,846.7% (ECE) for NOx, while falling below of the Egyptian regulatory limits by 2.67%. Because natural gas includes only trace amounts of H_2S; then SO_2 emissions from Zawia combined units of electricity are insignificant.

Table 6. Comparison of (*NOx*) emissions from Zawia combined power with five international standard limits (USEPA, 2010; LY, 2008; ECE, 2005; EG, 2005; and KSA, 2003)

Pollutant	Standards	USEPA	EG	ECE	KSA	LY
	Unit	*(lb/MW.hr)*	*mg/m^3 (E.G.)**	*mg/m^3 (E.G.)**	*lb/MBtu*	*mg/m^3 (E.G.)**
NOx	***Standard limit***	1.3	3,000	150	0.3	350
	Estimated value	19.1	2,920	2,920	5.591	2,920
	Deviation %	**+1,369.23**	**-2.67**	**+1,846.7**	**+1,763.7**	**+734.3**

*** E.G.:** ***Emitted Gases***

The excessive NOx emission from the studied power plant in comparison to almost international standard limits (USEPA, ECE, KSA, and LY) under steady-state conditions, due to the combustion was achieved with inappropriate operating conditions by using huge quantities of excess air input exceeding the optimum amounts of the required excess air (must be not exceeded 10%) (Ibrahim *et al.*, 2021b), also identical to the results mentioned by Ibrahim *et al*. (2012a) for the emission study from Khoms steam power plant.

3.2. Dispersion of NOx

Dispersions of NOx emission from Zawia combined power plant were analyzed with seasonal variation in meteorological data, as shown in Figures (3-6), for the spring, summer, autumn, and winter seasons, respectively, using Disper V4.0, depending on the concentration of pollutants resulting from the plant's simulation process. According to the modeling findings, the Zawia combined power plant is the primary source of nitrogen oxides in the area; NOx dispersions reach all the adjacent populated zones of Zawia city area.

In the spring season, the concentration of NOx reaches the maximum value near the coast, deep in the sea at the north-northwest of the source with a value of 4,603.37 $\mu g/m^3$ under the effect of winds blowing from a south-southeast direction (SSE). The concentration reaches a high value with 2,491.74 $\mu g/m^3$ at the coast of the West-Zawia zone then tends to decrease along the coast toward the north forest of Surman to reach 0.0 $\mu g/m^3$. Details of the maximum concentration recorded of NOx emitted from the Zawia combined power plant for the studied area are shown in Table (7).

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Figure 3. NOx concentration distribution from Zawia combined power plant based on the seasonal average wind (Spring season)

In the other adjacent regions (Zawia city, Jadda'm, Janzour, Al-Harsha, West-Zawia, Essabria, Surman, Abusurra, and Sabratah) no concentrations were recorded due to the prevailing monsoon from the SSE direction.

Table 7. The maximum concentrations of NOx emitted from Zawia combined power plant evaluated in the vicinity zones through seasons of the year

Zone \ Season	Spring	Summer	Autumn	Winter
West Zawia	2,491.74	1,771	5.34	0
Zawia	0	0	0	966
Al-Harsha	0	7,109.76	3,916.96	5,957
Essabria	0	734.37	0	0
Abusurra	0	0	0	23.48
Surman	0	909.47	0	0
Sabratah	0	123.69	0	0
Jadda'm	0	0	0	466.25
Janzour	0	0	0	52
Al-Swani	0	0	0	0
Al-Ajaylat	0	22.5	0	0

In the summer season, the prevailing monsoon blows from a north-northeast direction (NNE) as shown in Figure (4), so the maximum value of NOx concentration was recorded in the center of Al-Harsha zone at south-southwest from the source with a value of 7,109.76 $\mu g/m^3$ then decreasing towards the west at West Zawia with 1,771 $\mu g/m^3$ then Surman city with 909.47 $\mu g/m^3$, and towards the south of Al-Harsha at Essabria zone to reach 734.37 $\mu g/m^3$. Also, reached to 241.73 and 195.43 $\mu g/m^3$ in both south of Surman and the south of Zawia District zones respectively. There were also low concentrations in the southeast of Al-Ajaylat, and Sabratah recorded at 22.5, and 123.69 $\mu g/m^3$ respectively. While there were no records in the eastern zones of Zawia combined power plant due to the prevailing monsoon from the NNE direction.

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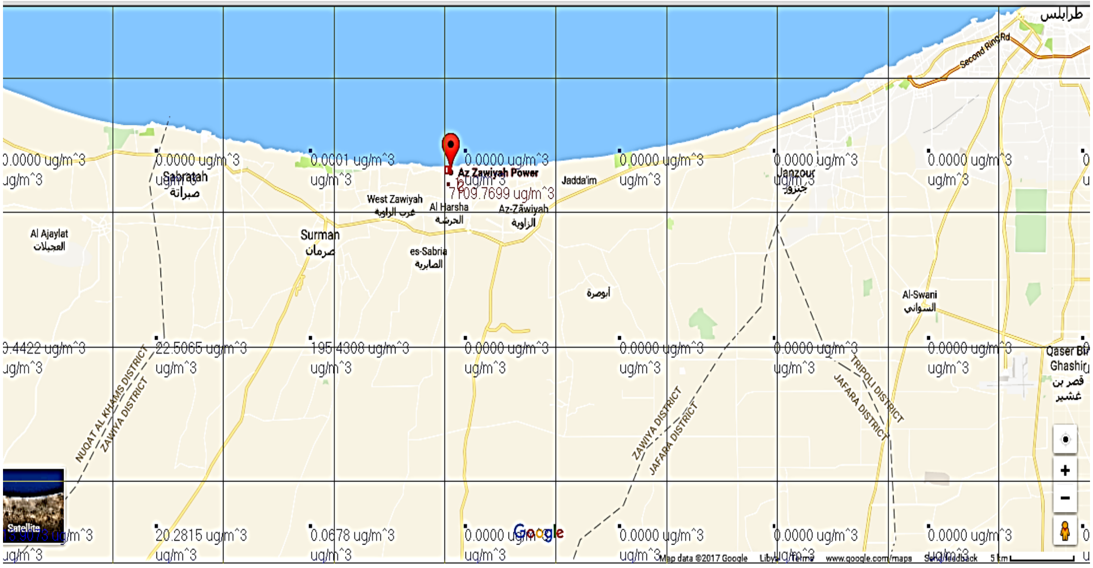

Figure 4. NOx concentration distribution from Zawia combined power plant based on the seasonal average wind (Summer season)

Figure (5) represents the dispersion through the Autumn season the concentration of NOx reaches the maximum value near the coast of the West Zawia zone deep in the sea north-northwest of the source with a value of 5,548.125 µg/m^3 under the effect of winds blown from south-southeast direction (SSE). Also, there are high concentrations recorded emitted from the source at the coast of Al-Harsha north-northwest of the plant reach to 3,916.96 µg/m^3 then decreasing towards the West Zawia to 5.34 µg/m^3. Also, there are not any concentrations recorded emitted from the source at any vicinity regions, due to the direction of winds toward the deep sea (from south-southeast).

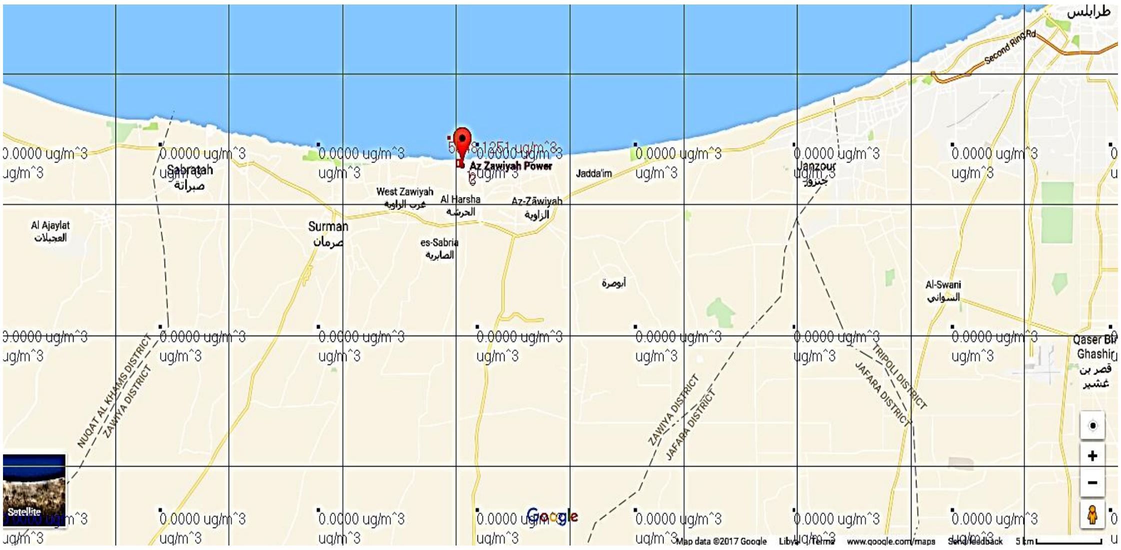

Figure 5. NOx concentration distribution from Zawia combined power plant based on the seasonal average wind (Autumn season)

In the winter season the monsoon direction from the west-southwest, so the maximum concentration recorded of NOx reach 5,957 µg/m^3 in the residential Zawia refinery and Zawia

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oil refining company east of the Zawia combined power plant. The concentrations are decreasing toward the middle of Zawia city, Jadda'm zone, and north of Janzour reaching 966, 466.25, and 52 µg/m^3 respectively. Also, low concentrations were recorded in the north of Abusurra at 23.48 µg/m^3; in contrast, there are not any concentrations recorded at any region's vicinity of the source (Fig. 6), due to the direction of winds from west-southwest towards east-northeast of the plant.

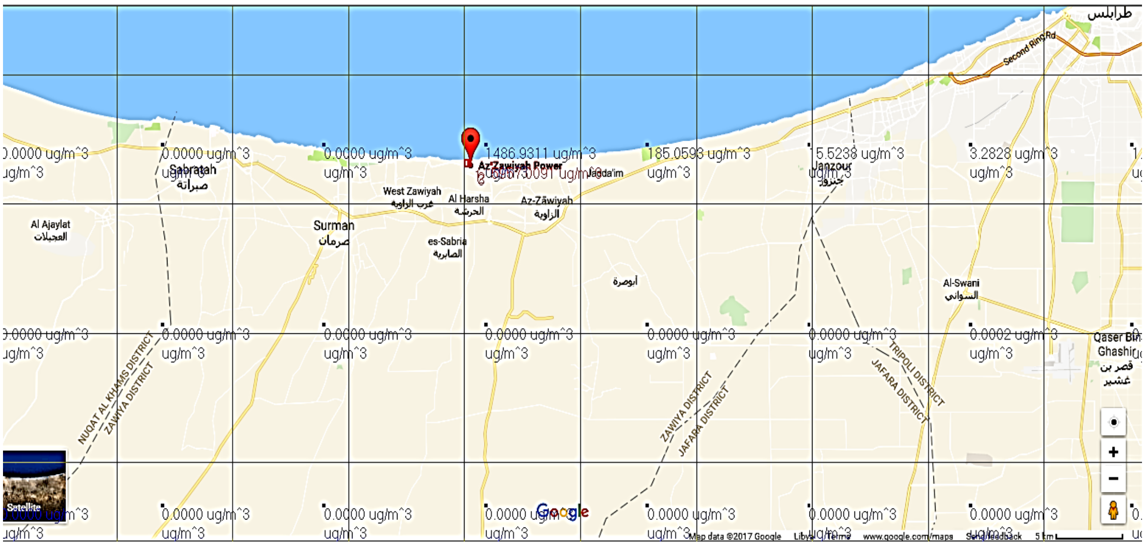

Figure 6. NOx concentration distribution from Zawia combined power plant based on the seasonal average wind (Winter season)

The presented results in Table (7) and illustrated by Figures (3-6) show that NOx represents the main emission from Zawia combined power plant reaching high values, particularly over the most populated area according to the prevailing wind direction. The most regions affected by NOx were Al-Harsha zone from summer to winter with values ranging between 7,109.76-3,916.96 µg/m^3, and Zawia center and Jadda'm with values reached 966 and 466 µg/m^3 respectively in the winter. In contrast, during the summer most populated areas have high concentrations of NOx whereas each of Al-Harsha, West Zawia, Surman, and Essabria, reached 7,109.76, 1,771, 909.47, 7,34.37, and 7,20.5 µg/m^3 respectively. Also, West-Zawia has a high concentration in summer with 2,491.71 µg/m^3. Generally, all these values are higher than the World Health Organization (WHO) limit of air quality, which is recommended that "exposure to NOx should not exceed 200 µg/m^3 for 1 hr". These concentrations are very high, especially since the wind direction from pollutant sources to the zone in some months of the year has been going on for a period of up to about 24 hours continuous, which means that the concentration obtained can last longer than 24 times the 1 hour of the proposed standards, this will threaten the population of this region to the incidence of respiratory diseases as indicated by some scientific studies. These concentrations are very high, which means that if adding other sources of NOx emissions from combustion processes (Zawia Refining Company) and transportation, they will get on high concentrations that exceed these values. Also, according to the other standards of air quality (USEPA, ECE, EG,

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KSA, and LY), the values of NOx concentration dispersed are without the range of these regulations.

For the other regions, NOx concentrations were located below the permissible limits (such as Sabratah and Al-Ajaylat ranged between 123.69-22.5 µg/m^3 in the summer season and Janzour and Abusurra in winter within 52-23.48 µg/m^3), or have no concentrations (Figs. 3-6) and represented in Table (7). This means that these regions may be safe from the effects of this gas but only from the current studied source.

3.3. Risk assessment of the emitted pollutants

In general, the studied regions vicinity of the Zawia power plant contains a high concentration of pollutants under study, which gives an indication that the environment surrounding these sources may be exposed to worker's health risks in the presence of mixing between all these pollutants, increasing especially in both cases of stagnation of stability of winds (Okasha *et al*., 2013), and therefore the health effects will be more severe than if the pollutants alone. However, these pollutants can be overcome or minimized at least in the case of occupational safety and protective procedures. So, according to the values that had been reached in this study estimated only from the source of the studied power plant within the studied area, it is well known that the studied area contains other sources of the pollutant (such as; Zawia Refinery located in Zawia city). Additionally, the studied area is classified as a commercial city and therefore it passes through daily a large number of means of transport of goods and trucks of various shapes and sizes as well as other means of transport, which are all the primary sources of such pollutants (non-fixed sources), which in turn will work together as well to emit large quantities and increase the proportions and concentrations of these pollutants in the studied regions. Therefore, based on the obtained results here, especially with the scarcity of such studies in the past and the scarcity of information, it can be said that the studied areas are subjected to large and continuous emissions over the past years of such pollutants and others, which may cause a defect in specifications and thus cause damage to air quality and the possibility of health effects on the components of the living environment and damage to their contents.

Consequently, according to WHO regulations the obtained range of NOx specially Al-Harsha zone (7,109.76-3,916.96 µg/m^3) from summer to winter seasons, West-Zawia in both the spring and summer with values reaching 2,491.74 and 1,771 µg/m^3 respectively, Essabria and Surman in summer within (909.47-734.37 µg/m^3), and Jadda'm with 466.5 µg/m^3 in the winter. So the (long/short term) exposures of nitrogen oxides will be effective in general on the human and animal imbalance caused by the respiratory functions and pulmonary hypertrophy lung and perhaps lead to rupture of the mucous membranes of the respiratory tract. In some concentrations, it may also lead to abnormalities in blood and yeast synthesis and may lead to death at high concentrations (WHO, 2005). The adverse effects of nitrogen oxides on human respiratory performance in asthma patients are increased, respiratory function of these patients, especially children, is negatively affected when exposed to low concentrations of nitrogen dioxide (Afifi, 2000). It has been found that NO_2 concentrations of

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around 1,880 g/m^3 can cause metabolic alterations in animal lungs. Animals exposed to about 990 g/m$_3$ NO_2 for 6 months suffer from alveolar rupture and increased susceptibility to bacterial infections (NAAQS, 2008; and Nicholas, 2002). Furthermore, gaseous emissions are blamed for chemical interactions with calcareous stones and marbles of human heritage sculptures and columns, causing their qualities to vanish. (Roots, 2008). Also, the presence of nitrogen oxides in the air is generally disruptive and disturbances some of the vital functions of the plant or damages some parts and leads to the fall of leaves, and may sometimes lead to the symptoms of severe deficiency in the Chlorophyll substance (jaundice), which will lead to the imbalance and disturbance in all the vital functions of the plant (Al-Satuf, 1995).

3.4. Environmental impacts of emissions by using WAR Algorithm

The potential environmental impact is the unrealized effect or influences that mass and energy emissions might have on the environment on average; so, it is simply a probability function for the occurrence of a prospective impact. As a result, the possible environmental implications of chemical manufacturing processes are often driven by the energy and materials that the process consumes or releases into the environment. No potential environmental effect meters exist because the potential environmental impact is a hypothetical number that cannot be physically measured. However, considering functional relationships between the two, one may compute possible ecological effects from linked quantifiable quantities. This is a regular occurrence in science and engineering (Cabezas *et al*., 1999).

However, there are eight main types of impact. These are classified as four environmental physical potential impacts (acidification potential, greenhouse effect, ozone depletion, and photochemical oxidant production), two human toxicity effects (ingestion and exposure), and two ecotoxicity effects (aquatic and terrestrial) (Cabezas *et al*., 1999). So, using the Aspen-Hysys material and energy balances data as input to the WAR algorithm, the total output rate of possible environmental consequences of the process per hour (Fig. 7). The primary potential environmental impacts of the power plant include high values for Smog Formation Potential (PCOP= 41,500) and Acidification Potential (AP= 39,800), followed by Human Toxicity Potential by Exposure (HTPE= 2,210), Terrestrial Toxicity Potential (TTP= 520), and Aquatic Toxicity Potential (ATP=186). In addition, the power plant has a Global Warming Potential impact of 1,130 per hour due to CO_2 emissions. So, according to existing scientific literature, these findings confirm the evidence presented above and demonstrate that it is harmful to the environment.

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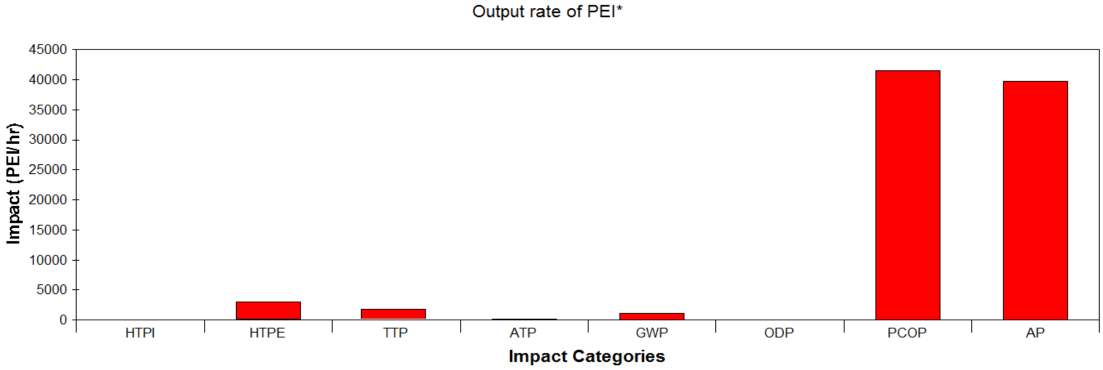

Figure 7. Total output rate of (PEI/hr) from Zawia combined power plant
**Inputs do include the impact of product streams and do include the impact of energy generation.*

4. Conclusion

The current research was carried out on the Zawia combined power plant in Libya. Despite these constraints, some results from the modeling and simulation approaches have been obtained. The findings of the Aspen-Hysys modeling approach coincided well with the facility's field data, revealing that NOx and CO_2 emissions are the principal pollutants produced by the combined power plant. The NOx emission dispersion from the Zawia combined power plant has been studied using Disper V4.0 for the concentration of pollutants arising from the plant's modeling process based on seasonal meteorological data. According to the dispersion of air pollutants concentrations, the atmospheric air of the surrounding regions of Zawia city is contaminated, which has a negative impact on the environment and the health of the inhabitants. Finally, WAR algorithm analysis shows that there is a gradient in concentration effects connected with emissions, which can have a direct influence on public or environmental health, and the current study's findings assist in focusing resources on the most relevant pollutants. It may be argued that tighter emission management over such industrial units is required to decrease emissions to a bare minimum in order to fulfill acceptable limits set by the World Health Organization's international air standards.

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